The Impact of New Technology on the Corn Sector: 1998 Update and Prospects for the Future

by
Peter A. Riley[1]

Abstract: Expansion of new technology such as Bt corn is proceeding quickly and is likely to increase for the next few years. Incentives such as cost savings, reductions in input use, and yield advantages that can increase net returns are driving farmer adoption. The spread of corn with value-enhanced traits is at an earlier stage of development than corn with crop protection features, but will also expand if there are economic incentives. Growth of value-enhanced corn could lead to more extensive changes in pricing and marketing.

Keywords: Corn, Bt, genetically modified, value-enhanced.

Acreage of Bt corn and other new corn varieties is expected to increase sharply in 1998, following strong growth in 1997. Farmers' widespread interest in new technology and expansion of new products signal the beginning of a new era for the corn sector in which biotechnology and value-enhanced traits are expected to play prominent roles.[2] This is still a very early stage for the new technology, and there will be continued change and, for many products, improvements along the way.

There has been a tremendous investment in corn research by private companies recently, suggesting the brisk pace of innovation is expected to continue. Over the next few years, more new corn seed technology will reach the marketplace which could have a wide range of economic impacts on production, marketing, trade, and pricing. If some of the developments identified by industry come true, eventually it will become more difficult to just call corn "corn" because of product differentiation.

The seed technology for corn can be broadly characterized in two categories. First, there is technology that generally reduces input use or leads to more effective input use and that is mainly developed through biotechnology. The major product to date is Bt corn that is resistant to an insect pest, the European corn borer. Herbicide-resistant corn is also on the market now, but this will be probably used on a smaller scale than Bt corn or Roundup Ready soybeans in 1998. In addition, there is some herbicide-resistant corn available that was developed through conventional breeding.

Second, there is corn with enhanced-value traits aimed at specific end uses, such as high oil corn, hard endosperm corn, waxy corn, and white corn. These have been developed through conventional breeding, and some of these types are already established on a relatively small scale. This distinction between categories is expected to become blurred over time, however, as genes are stacked to enable the use of genetically modified seed in conjunction with high-value traits. Limited quantities of stacked hybrids are available in 1998: some combine Bt protection and herbicide resistance, and others combine resistance to two kinds of herbicide.

Acreage Outlook for 1998

Industry sources indicate Bt corn could be planted on as much as 15-18 million acres in 1998, up from under 5 million in 1997. Depending upon total plantings, Bt corn could amount to close to 20 percent of all corn in 1998. It is probably more difficult to pin down the range for herbicide-resistant corn. It appears that seed will be available for around 13-15 million acres, up from perhaps 4 million acres planted in 1997. (This category includes corn resistant to a number of different herbicides, see page 22 for details.) Thus, if farmers' use approaches the supply of seed, acreage of genetically modified corn and other corn based on new technology could exceed 25 million acres. This would be in the neighborhood of transgenic soybeans plantings, with forecasts for Roundup Ready soybeans mostly running around 20 million acres or higher.

[1]Agricultural economist, Market and Trade Economics Division, Economic Research Service.
[2]Biotechnology as used here refers to a set of tools that use living organisms to solve problems or make useful products. Organisms that are genetically engineered or modified are often referred to as genetically modified organisms (GMOs) or transgenic. Value-enhanced refers to particular quality characteristics that add value to corn for one or more types of end-use.

Expansion of value-enhanced corn is likely to be less than Bt or herbicide-resistant corn in 1998. Acreage of the major new product, high oil corn, is targeted by the providing company to reach over 1.5 million acres. If realized, this would about double the estimated 700,000-750,000 acres planted in 1997. However, early evidence from seed companies indicates acreage will probably not increase that much this year.

Acreage increases are also expected in 1998 for some, but not all, of the other special trait corn that is based on existing technology. A fairly strong gain in white corn plantings is expected because of higher price premiums. In 1997, industry sources estimated white corn at 550,000-575,000 acres. Waxy corn is also likely to increase from nearly 600,000 acres grown in 1997. Acreage of hard endosperm or food grade corn is expected to be stable, remaining around the 1997 range of about 750,000 to 850,000 acres. This category is somewhat loosely defined, according to the U.S. Feed Grains Council, since many hybrids with food grade characteristics are grown because of good yield potential and are not processed for food. Finally, little or no change appears in store for high amylose corn, at around 35,000 acres, and high lysine corn, around 30,000 acres.

USDA does not collect separate acreage, production, or other data on these specialty or new varieties, but they are included in total corn data. Industry sources were consulted to develop estimates and forecasts cited here, and thus any numbers referring to specific types of corn are not official USDA data.

Leading Products

Bt Corn

Bt corn is aimed at resisting damage from the European corn borer (ECB), a major insect pest that is widespread in the Corn Belt, particularly in the western and northern regions. Bt corn is enhanced with a gene from a naturally occurring soil bacterium (Bacillius thuringiensis) that produces proteins that selectively kill specific groups of insects, such as the corn borer, but have no direct effect on others, including beneficial insects. Corn borers disrupt the corn plant's growth and reduce yields. However, because the borer tunnels inside the stalk, the impact is not always readily apparent until damage has occurred.

Farmers pay a premium for the Bt corn seed, which is available from many seed companies and incorporated in an increasing number of hybrids. For those farmers who spray against borer, the higher cost of the seed is offset by savings on chemicals. Because of the difficulty in predicting infestation and in properly timing treatment, the effectiveness of spraying has been mixed, and not all the farmers who grow Bt corn treated their fields previously. Given favorable yield indications, many farmers are apparently planting Bt corn as a form of insurance just in case there is bad infestation, and higher yields can more than offset the added seed costs.

Bt corn was first approved for sale in 1996, but availability and use was limited. In addition, ECB infestation was generally light in 1996, and did not provide a strong test of the technology. In 1997, use expanded greatly and corn borer infestation was relatively high. Results were generally very positive in terms of protection from borer damage, as judged by looking at adjacent non-Bt corn. For the most part, the Bt technology worked well, but the yield performance was dependent on the particular hybrid, and tended to be better in northern parts of the Corn Belt. In side-by-side comparisons, yields of Bt corn varieties in some areas were higher than non-Bt corn and dramatically higher where infestation was very heavy.[3] However, much of the early Bt corn is attached to somewhat dated genetics, and the industry expects yield results to improve quickly as Bt becomes available with more elite germplasm.

Herbicide-Resistant Corn

Some herbicide-resistant corn is also on the market now, with varieties resistant to popular herbicides based on glyphosate (Roundup) sold as Roundup Ready corn, glufosinate ammonium (Liberty) sold as Liberty Link corn, and imidazolinone (such as Pursuit, Lightning) known as IMI corn, and also as IT(imidazolinone tolerant) or IR(imidazolinone resistant) corn. There is also some herbicide-resistant corn developed through conventional breeding, including corn resistant to sethoxydim (Poast). For 1998, seed is available for more than 7 million acres of IMI corn, over 6 million acres of Liberty Link corn, and possibly as much as 900,000 for Roundup Ready corn.

One seed company official noted that the outlook for farmers' response to herbicide-resistant corn is more complicated than for insect control such as Bt corn, suggesting a somewhat slower expansion. Weed problems tend to be more varied, both by geography and by year, than insects. Like all the different corn products, the usefulness and performance will vary by region and management practices. In areas where crop rotations and conventional tillage are more common, weed control may be less dependent on herbicide use. Combining herbicide tolerance with insect resistance will probably accelerate their adoption.

High-Oil Corn

High-oil corn (HOC) has seen rapid growth since its commercial introduction in 1994. Acreage doubled in 1996 and again in 1997. Research efforts have been led by a major chemical company, and the technology made available

[3]This is based on industry, media, and extension sources, not any official USDA data.

through many seed companies. There has been a major advertising campaign mounted, more marketing opportunities established relative to older generations of specialty corn, and even use of the Internet to post information, such as participating elevators, the premium schedule, and sample contracts. These efforts contributed to sharply raising interest in this crop.

Conventional corn typically contains 3.5 to 4 percent oil, whereas high-oil corn can contain 7 percent or even more. It is mainly attractive because of its good feeding characteristics, rather than for the oil, per se. The extra oil boosts the energy content of the feed, eliminating or reducing the need to add fat to the ration, as well as reduces the need for supplemental protein or some amino acids. Added benefits are less dust and good mixing and grinding traits. As part of an identity-preserved delivery system,[4] HOC also should have less variability for end users than normal purchases of corn.

Although HOC hybrids that are grown like conventional corn are available, most growers are using the Top Cross system because the potential oil content is higher. In the Top Cross system, a portion of the field (about 8-10 percent) is planted with very high oil pollinators, while the rest is planted with male-sterile hybrids. The pollinators are low yielding, but offer a longer pollen shed than traditional hybrids, and boost the oil in the other plants. The recommended plant population is higher than normal corn to offset yield loss from the pollinators. Larger fields and/or buffer strips are recommended to prevent stray pollen from normal corn, reducing the oil content of the corn.

While many test results show comparable HOC yields to regular corn, some industry officials identify the risk of slightly lower yields than normal corn, mainly reflecting more risk at the pollination stage. In addition, the oil content is variable, depending on growing conditions, soil types, and other factors. These risk issues appear to be an obstacle blocking faster adoption by farmers, along with concern about the price premium. Premiums for high-oil corn are offered on a sliding scale based on the oil content of the corn delivered, and, if large enough, the premiums will cover the additional costs of producing and segregating the corn, plus cover any yield drag if this were to occur.

Demand for high-oil corn is expected to increase as users gain familiarity with it and the volume available becomes larger. Trials by many large users are underway. The earliest gains have been in export markets and in on-farm feeding use by growers who can avoid the need to purchase and store additional fats. Most of the HOC exports are going to developing, tropical countries, where supplies of fat are expensive or unreliable, including markets in Asia, Latin America, and the Caribbean. Expansion of HOC corn to larger U.S. feed users, such as the big integrators, is expected, but the timing is difficult to predict because of the need for large quantities.

[4]Identity preserved means the product is segregated to avoid commingling with other products all the way from harvest to delivery to the end user.

Despite the numerous feeding advantages identified, a key economic issue that will shape demand is the price of competing feed ingredients. In the United States, the huge supply of grease and fats from the fast food industry and other sources, and the high cost of their disposal, will likely provide strong competition for high-oil corn. Like other aspects of new corn technology, combining the high-oil feature with other traits will increase the market potential.

Future Developments

Seeds that are stacked with the Bt trait and resistance to various herbicides are expected to increase substantially in 1999 and continue to grow in the future. The next major insect resistance feature is one to deal with the corn rootworm. This will be introduced in the next 2 or 3 years, and market prospects look good. Research is underway to develop resistance to more insect pests in the years ahead. Another focus of research is better resistance to diseases. Like many other desirable features, disease resistance has been a goal of conventional breeding and selection efforts. The initial emphasis of genetically modifying corn has been more toward insect and weed control because of the greater expected economic impact.

For enhanced-end traits, there will be both new products introduced and improvements in existing traits, along with stacking to combine various traits with insect and/or herbicide resistance. In addition to high-oil corn, there has been considerable interest in the development of low phytate corn that is expected to reach the market soon, in 2 or 3 years. This corn is low in phytic acid and enables poultry and hogs to better utilize phosphorous, thereby reducing the amount of phosphorous excreted, and reducing odor and runoff problems. Many other traits to improve feeding value or tailor the corn to special feed needs will be emphasized based on higher protein, higher content of amino acids such as lysine or methionine, or altered fatty acid profiles. These traits are sometimes categorized as nutritionally dense corn. In addition to improved feeding traits, research is underway to provide corn with desirable traits for various food and industrial products from wet milling, dry milling, and alkaline processing. Some of these traits include starch content, susceptibility to cracks, and various milling characteristics.

The vision of the seed industry is that corn will become more specialized over time to fit the particular needs of end users. Thus, rather than just buying number 2 or 3 yellow dent corn, a buyer will specify various traits required for the type of animals being fed or for the specific industrial or food product. In some cases, a particular hybrid will be specified. Based on trends that are beginning to emerge, end-use corn specialization and marketing are no longer a far-fetched idea. While the technology is getting closer, however, it will only develop if the economics are favorable.

Economic Implications and Issues

Historical perspective on specialty corn—Yellow dent corn dominates in the United States, and the various specialty corns, excluding high-oil corn, collectively account for only about 5 percent of the market. As a preface to looking ahead, a brief glimpse backward might be instructive.

The track record of white corn, one of the leading specialty types, has been mixed. Plantings reached nearly 700,000 acres in the mid-1970's, (at that time data were tracked by USDA), but then sunk as low as 300,000 acres by the early 1980's. The market was relatively thin, and included a very volatile export component. In addition to market risk, the average yield of white corn is lower than yellow corn, and many growers were discouraged, despite the potential for premiums. By the 1990's, white corn acres began to rebound, spurred by solid domestic demand for white corn for snacks and Mexican-style foods and increasing exports. Most production is under contract, and premiums can exceed 40 cents per bushel, sufficient to allow for reduced yields and other higher costs. However, the seed industry expects some recently released hybrids to match yields of yellow corn.

The focus of the most successful specialty corn has been food use and to a lesser extent, industrial use. Much hard endosperm and other food grade corn goes into snack foods. Waxy corn, for example, is used for food starch because it contains no amylose which is a less digestible part of ordinary corn starch. Relatively mature demand accounts for recent modest growth in these categories. The market for feed corn has been almost untouched, however. Some specialty corn for feeding has been available for years, but growth has been stagnant. For example, high lysine corn was introduced about 30 years ago. Lysine is an important amino acid for hogs, but it is limited in corn. The combination of low yields and the lack of a large enough premium to cover higher costs has constrained growth. Users have alternative means of improving the amino acid balance, such as synthetic lysine.

Production that is linked to an assured buyer—and thus reduced marketing risk—is one of the keys to success in specialty crops. One major snack food company has developed a successful supply channel with Nebraska farmers, who produce specified varieties of white and yellow food grade corn. There have been many similar developments like this in recent years on a localized basis, not just for corn, but for soybeans and other field crops. Another critical need is a price that is sufficiently high to cover additional costs such as lower yields or special handling.

Adoption—U.S. farmers are highly receptive to new technology, particularly given their widespread interest in gaining more value to their products or reducing costs. Adoption of some of the first new biotech seeds, such as Bt corn and Roundup Ready soybeans, has been quick despite the extra cost of the seed. Farmers will readily pay premiums for the technology if the benefits are perceived to outweigh the costs. Still, with so much new technology coming on stream, and limited test data from public sources, many farmers will wait to plant some new varieties until performance can be proven on the local level.

Early indications of the effects of many of the new technologies are favorable, although adoption is not without risk. Along with the sustained performance over time, performance of the new technologies under stress conditions, such as a drought, is an unknown that could influence future adoption rates. For value-enhanced corn, the size of the price premium will be a critical factor, and prices of competing substitutes will be a critical factor in shaping demand. In addition, changing market conditions could be a factor, if higher production were to lead to a lower price premium for some end traits, for example, especially in thin markets.

Environmental benefits—Additional pressures from the environmental side—at the farm and for end users—could help to promote adoption of new technology. Much of the new corn will mean less chemical use, adding to its appeal. Corn with enhanced feeding value can improve the digestibility of certain nutrients, so less nutrients will end up as animal waste. This should reinforce the willingness of end users to pay premiums for the corn's improved feed efficiency.

Management requirements—In addition to cost savings, one of the biggest incentives to adopt some new technology is convenience and, in some cases, its compatibility with conservation tillage practices. For example, Bt corn can reduce the management load on growers by potentially reducing scouting needs and eliminating some insecticide use. Incentives to use herbicide-resistant crops are also strong, as growers can simplify herbicide use and often reduce applications. The promise of stacked traits could similarly contribute to reducing management requirements.

The proliferation of new herbicide-resistant crops could cause confusion, however, as it becomes more difficult to keep straight which herbicides can or cannot be applied to a particular crop, especially when replanting or dealing with any potential residual carryover. In addition, knowledge of the optimum times to apply the herbicides with these products is still evolving.

Aspects of some new corn varieties will clearly increase management demands. This would be most obvious for corn with special production needs. For example, high-oil corn, like seed corn, needs additional attention to prevent cross pollination, which could reduce the oil content. Handling needs will also increase for value-enhanced crops as a particular crop's special characteristics must be maintained from the producer to the end user.

Yield effects—Most of the new technology introduced so far could be considered yield "neutral" to the extent it is not explicitly aimed at increasing yields. However, the technology may have yield effects, both positive and negative, not just from developments in genetics, but from changes in management demands. In general, elite germplasm will still be the underlying driving force in future productivity gains, regardless of the new technology attached. As discussed in the section on Bt corn, in the rush to bring new products to market, some of the genetics used are dated, and yields of conventional hybrids may be higher, but this is expected to diminish quickly.

Some of the new products will effectively boost yields by cutting losses to pests or weeds, protecting whatever yield potential is already present in the particular hybrid. Benefits will vary from year to year and over different locations depending on environmental factors such as the amount of pest infestation. There is no solid estimate on yield loss at the national level due to pest damage. Thus, it is hard to judge the impact on aggregate yields from adoption of Bt corn. But if adopted widely enough, and if yield advantages are sustained, then it could "bump" the average U.S. yield above the long-term trend.

Despite attention to numerous other factors, increasing yield has been the traditional focus of the corn seed industry. The focus of most enhanced-value crops is an attribute for end use, however, and, in some cases, yields may be compromised. Farmers are very reluctant to grow corn if they perceive lower yield potential unless there is a clear price premium to compensate. Over time, gene stacking and more research may be able to overcome any yield penalties of the enhanced trait corns. Biotechnology increases the tools available to scientists, and its use should speed the pace of research, with positive implications for yields.

Pest and weed resistance—Although industry is taking preventative measures, some critics are concerned that insects or weeds may develop resistance to the technology intended to suppress them, and they have expressed vocal opposition to the use of Bt in corn and cotton. They fear resistance could reduce its effectiveness for other uses as well. Traditional use of Bt foliar sprays was less worrisome because the Bt was quickly broken down by sunlight, and insects had very short exposure, compared with Bt corn where it persists in the crop throughout the season.

The companies selling Bt seed have a very strong economic incentive to prevent resistance to preserve their markets, and they acknowledge the danger and even the likelihood that resistance will eventually develop. Producers using Bt seed must agree to certain production practices designed to slow or prevent the development of resistance, such as not planting 100 percent of their fields in the Bt variety in order to provide a refuge for the survival of non-resistant insects. In many cotton growing areas where Bt cotton may be grown, use of Bt corn has been restricted to prevent resistance.

Another aspect that may help prevent or delay resistance is the introduction of additional Bt genes that have different modes of action, and one is expected to be approved momentarily by the Environmental Protection Agency (EPA) and USDA. It employs a protein that attaches to a different part of the insect than the protein most widely used now. If resistance were to develop, the seed industry is prepared to tap different strains and versions of Bt, and offer new generations of product, similar to what is done with some antibiotics. The effectiveness of these measures will need to be evaluated over time.

Continued use of a single herbicide raises fear of weed resistance as well by some critics and by some farmers. Again, the companies involved have very strong commercial incentives to prevent this. Some extension agents point out that weed resistance may be less of a concern than weed shift, when the species most susceptible to the herbicide decline over time, while less susceptible species build up.

Marketing—The growing emphasis on end traits implies changes in the marketing system, with more identity preservation changing the traditional bulk commodity focus of corn, the largest field crop. If taken far enough, this trend to more emphasis on end use traits will reduce—not eliminate—the traditional bulk focus of the commodity markets, which emphasize large volumes and blending.

With more trait orientation, testing and certification will become critical. The extent of growth partly hinges on technical factors—the complexity and quality of end-quality testing along with the expense. Industry sources are optimistic about near infra-red reflectance spectroscopy testing, used to measure the oil content of corn when the farmer delivers the corn. It gives a quick (about 45 seconds) and reliable result. This testing can be used for certain other traits, as well, such as protein and starch content. Movement to this type of testing is a significant change from current practices, however. The existing system of grades and standards does not identify the inherent traits of the crops. While some feeders run assays on corn and other feed ingredients, it is not routinely done at the country elevator.

Contracting as a means of coordination from the farm to the consumer will likely expand, as well as the role of niche marketers who link growers with buyers. Another possible outcome is more integration where successive stages of the production and marketing chain are linked together, for example, under direct ownership or through cooperative arrangements.

Among the key issues is who will capture the value created by new technology. There has to be some allocation for all parties in the marketing chain to provide incentives to develop the seed, and then to grow, elevate, handle, and transport new products. Exactly how the value is shared along the chain will evolve over the coming years.

The providers of new technology have started to devise arrangements that respect the intellectual property rights that are critical in providing incentives to invest and develop products while allowing successful commercialization. An analysis done a few years ago raised the possibility that diffusion of biotech-derived products would be slowed by monopoly pricing opportunities afforded by patent protection [Fleisher, 1989]. Despite numerous legal battles involving things such as patent rights, however, pricing issues have largely been avoided as indicated by the very rapid spread of new technology like Bt corn and Roundup Ready soybeans. In the seed and chemical industries, there has been an incredible wave of alliances, mergers and acquisitions, joint ventures, and licensing arrangements undertaken in the last few years that could lead to further change elsewhere in the corn industry if more links are established to processors and users.

Trade—In late 1997 and early 1998, there was friction in the European Union (EU) about acceptance of U.S. corn and corn product exports because particular Bt varieties had not yet been approved under the EU's approval process. Some varieties were recently approved by an EU scientific advisory panel and an EU regulatory committee, but there are still more hurdles to clear before final approval. The EU also has enacted a broad labeling requirement. The rapid introduction of new genetically modified varieties and a slow approval process in the EU suggests delays could occur again under the prevailing regulatory system. If difficulties persist, some U.S. corn processors who export to these markets may prefer to avoid purchase of Bt or other genetically modified corn for their operations.

Most countries have not placed any restrictions on imports from the United States, and expansion of genetically modified corn should not disrupt trade. Furthermore, other corn exporting countries are likely to grow genetically modified corn in the future, limiting possible alternatives. Niche markets for corn that does not contain GMOs may develop in some foreign markets if consumers are willing to pay more. Because of interest in value-enhanced products, expansion of identity-preserved corn trade is likely. Recent growth in U.S. exports of high-oil corn indicates this is a realistic possibility.

Pricing—Most of the new technology is proprietary, and premiums are charged for the seed. For some products, the premium covers technology fees or gene fees that go to the originating company. Through various licensing agreements, payment of fees, and numerous corporate alliances, the technology is generally available from many different seed companies.

On the output side, the crops that are genetically modified should have little or no direct impact on prices received by farmers, assuming the varieties are approved under the regulatory process and are accepted by consumers and other countries. This is because the products are basically indistinguishable from conventional crops. For a relatively small group of consumers, a niche market for non-GMO products may develop, similar to the present market for organic foods, that will involve separate identity-preserved marketing and thus premium prices. (The seed industry has requested in some cases that growers segregate specific genetically modified varieties that have not been approved for import by some foreign countries.)

Enhanced-value products do imply changes, however. Product prices will be higher: first, to reflect the value of the end-use trait, and second, to cover the higher costs involved in keeping and transporting the crops separately. Segregation or identity preservation will be required at all points in the marketing chain, starting at the farm. More contracting is expected as a means to assure a guaranteed market for farmers and minimize risk, similar to the way many vegetables and some specialty corn are currently contracted. However, contracting does not necessarily eliminate risk. If a producer fails to meet contract specifications due to quality problems, there may be no premium earned.

Evaluating the economic effects on overall prices and returns from more value-enhanced crops will hinge on the extent these products are grown. If the products remain as specialty crops only, there will be a fairly small impact, but if the products become very popular, larger changes will occur. As more farmers grow enhanced-value crops, the size of the premium needed as an incentive to farmers could change. Economies of scale could also reduce marketing and transportation costs if adoption is widespread. From the user's point of view, the price of substitutes, such as grease that competes with high-oil corn, will also adjust, and in turn influence the price of the corn.

The main commodity market for corn is likely to remain an important reference point in the price determination process for value-enhanced corn. Users of specialty corn typically offer a premium relative to a spot or futures price. This has basically occurred at the local level adjusted for basis with a limited number of elevators buying a particular product. Sometimes farmers can deal directly with a processor. As production expands, the range of marketing opportunities should expand and more elevators will buy value-enhanced corn. As the first of this new wave of products, the case of high-oil corn will be instructive with the attempt to build a large marketing network, along with the use of the Internet as a means of price discovery.

Conclusions

The seed corn business in the United States is one of the most dynamic industries in the country, as judged by its innovations that have been an essential part of strong productivity growth. The results reflect a long tradition of research at the public and private level that is now backed by massive investment from chemical companies and others. Despite impressive new soybean products from the same companies, corn technology is probably leading the pack relative to other crops with a wider range of developments. This reflects corn's status as the largest U.S. crop and the fact that virtually all corn seed is purchased, providing large potential returns to investment. The seed companies continue to turn out new hybrids, and they get seed to the market quickly by supplementing U.S. operations with winter production of seed in Argentina and Chile in the Southern Hemisphere.

Expansion of new technology in the corn sector is proceeding quickly and is likely to increase for the next few years. Strong incentives related to cost savings, reductions in input use, and yield advantages that can increase net returns are driving farmers' adoption of corn seed derived from biotechnology. The distinction between different seed varieties developed with new technology will become increasingly blurred in the future through the use of gene stacking. The spread of corn with value-enhanced traits is at an earlier stage of development, but its expansion could lead to more extensive changes in pricing and marketing. The economic relationships that allocate the value added by new products across the various participants and share the risk are just starting to evolve.

References

American Seed Trade Association. (1996) "Proceedings of the Fifty-First Annual Corn and Sorghum Research Conference 1996," Publication No. 51.

Caswell, Margriet F., Keith O. Fuglie, and Cassandra A. Klotz. (1994) *Agricultural Biotechnology, An Economic Perspective*. Agricultural Economic Report No. 687. USDA, Economic Research Service.

Fleisher, Beverly. (1989) "The Evolving Biotechnology Industry and Its Effect on Farming," *Agricultural-Food Policy Review*, Agricultural Economic Report No. 620. USDA, Economic Research Service.

Hill, Lowell D. (1990) *Grain Grades and Standards, Historical Issues Shaping the Future*. University of Illinois Press.

Union of Concerned Scientists (1997). "The Gene Exchange." Fall 1997.

University of Minnesota Extension Service (1997). "Bt Corn and European Corn Borer, Long-Term Success Through Resistance Management."

U.S. Feed Grains Council. (1997) "1996-1997 Value-Enhanced Corn Quality Report."